CANMET

REPORT 83-2E

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

McMASTER, AN ALLOGENIC MASSIVE SULPHIDE COPPER DEPOSIT, BATHURST AREA, NEW BRUNSWICK

J.L. JAMBOR

18pp

MINERALS RESEARCH PROGRAM
MINERAL SCIENCES LABORATORIES

OCTOBER 1982

Energy, Mines and Resources Canada
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Canada

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Catalogue No. M38-13/83-2E
ISBN 0-660-11377-5

Canada: $3.25
Other countries: $3.90

Price subject to change without notice.

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Canada: $3.25
Hors Canada: $3.90

Prix sujet à changement sans avis préalable.

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by

J.L. Jambor*

ABSTRACT

The McMaster deposit near Bathurst, northern New Brunswick, consists of massive and disseminated pyrite in phyllite of the Ordovician Tetagouche Group. The deposit is small, averages only 0.7% Cu, and unlike most massive sulphide prospects in this region, the sphalerite and galena content is subordinate to that of chalcopyrite. Fine-grained, poorly layered pyrite is present in only small amounts, and most of the massive sulphide consists of coarser, allogenic pyrite. Other minerals present in trace amounts are lead-bismuth sulphosalts, bismuthian tetrahedrite, tennantite, arsenopyrite, native bismuth, pyrrhotite, magnetite, and supergene copper sulphides. The principal silicate in the pyritite is quartz; chlorite is common whereas carbonates are represented only by trace amounts of siderite. Phyllite with abundant muscovite and disseminated sulphides is gradational to massive sulphides that are in sharp contact with chloritic rocks almost devoid of muscovite. The chloritic zone is mainly conformable, 10 to 15 m thick, and is continuous along the strike length of the massive sulphides.

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LE DÉPÔT McMASTER: UN DÉPÔT ALLOGÈNE MASSIF DE SULFURE DE CUIVRE DANS LA RÉGION DE BATHURST AU NOUVEAU-BRUNSWICK

par

J.L. Jambor*

RÉSUMÉ

Le dépôt McMaster, situé près de Bathurst au nord du Nouveau-Brunswick, est constitué de pyrite massive et dispersée dans de la phyllite, du groupe Tétagouche Ordovicien. Le dépôt est petit, et ne contient en moyenne que 0,7% de Cu. Contrairement à la plupart des dépôts massifs de sulfure de la région, la quantité de galène et de sphalérite qu'on y retrouve est inférieure à celle de la chalcopyrite. On ne trouve qu'une faible quantité de pyrite dans des couches mal définies, alors que la majeure partie des sulfures massifs est composée de pyrite allogène, plus grossière. Parmi les autres minéraux traces, on reconnaît les sulphosels de plomb et de bismuth, la tétraédrite bismuthifère, la tennantite, l'arsenopyrite, le bismuth natif, la pyrrhotine, la magnétite et les sulfures de cuivre supergènes. Le principal silicate contenu dans la pyritite est le quartz. Le chlorite est commun alors que les carbonates ne sont représentés que par une quantité trace de sidérite. La phyllite contenant beaucoup de muscovite, et parsemée également de sulfures, est échelonnée avec des sulfures massifs, lesquels sont en contact direct avec les roches chloritiques presque dépourvues de muscovite. La zone chloritique est presque uniforme, de 10 à 15 m d'épaisseur, et elle se prolonge sur l'allongement des sulfures massifs.

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INTRODUCTION

Numerous Zn-Pb-Cu-Ag massive sulphide deposits occur in the Ordovician Tetagouche Group in a large area west of Bathurst and Newcastle, northern New Brunswick (Fig. 1). Although the general character of the deposits is known, few have been studied in detail, especially with respect to their sulphide mineralogy. This report on research being carried out at CANMET is one of several that provide technological and scientific data to assist in the development of mining and processing schemes for the New Brunswick deposits. They will enable governments and industry to plan resource development by improving the appraisal of economic exploitability of the deposits. The progressive accumulation of this information for several deposits will lead to an improved understanding of the nature of the massive sulphides, and, eventually, will provide an overview of regional variations in mineralogy and the effects of low-grade metamorphism. Further exploration, also, will be aided by a better understanding of ore genesis.

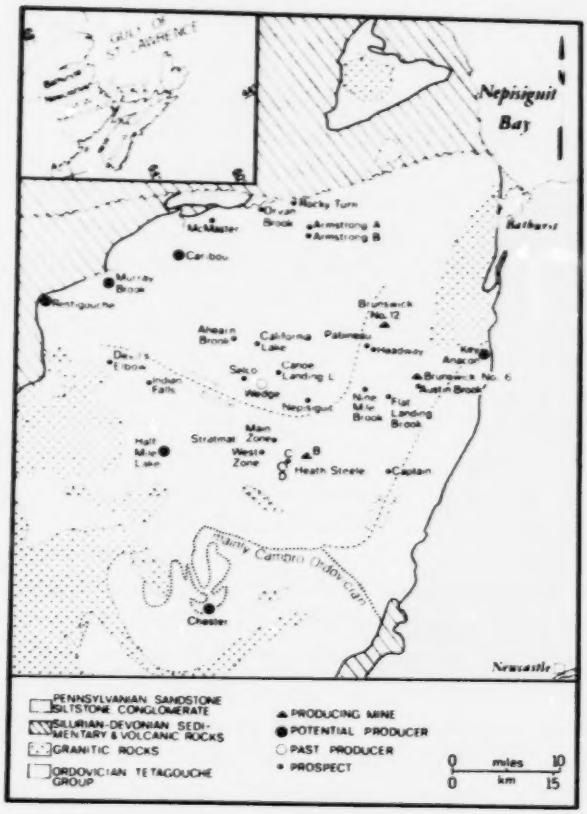

Fig. 1 - General geology and principal sulphide occurrences in the Bathurst-Newcastle district, New Brunswick. Geology and chlorite-biotite subzones of regional metamorphism compiled from Helmstaedt (1973), Irrinki (1973, 1974), Saif et al. (1978), and Plate 73-10, New Brunswick Mineral Resources Branch. The Caribou deposit, shown as a potential producer, also had a supergene-enriched copper zone that has been mined out.

The McMaster deposit, held by Anaconda Company (Canada) Ltd., is unusual in the Bathurst camp in that the principal sulphide of economic importance is chalcopyrite, and the ratio Cu:(Zn+Pb) is extremely high. The deposit is also of particular interest because its massive sulphides appear to be megascopically much coarser than the sulphides in nearby deposits such as Caribou, Orvan Brook, and Rocky Turn (Fig. 1).

GENERAL GEOLOGY

The McMaster deposit occurs in phyllites that are part of the Tetagouche Group (Skinner 1974) in an area mapped in detail by Fyffe (1974). The phyllites are about 300 m thick and strike about N70°E; dips are highly variable, but are generally steeply south to almost vertical. The phyllites are bounded on the north by massive to schistose basalts, and on the south by quartz-feldspar metaporphyry and schistose rhyolite that are in contact with red and black slates (Fyffe 1974).

At the McMaster property the phyllites are grey to dark green and variably muscovite- to chlorite-rich. Argillite and minor graphitic layers are present locally. Disseminated and massive sulphides are intercalated with the phyllite and form a zone that is about 100 m long and up to 10 m thick. Narrow sulphide intersections in drill cores indicate that the zone may extend to a depth of about 150 m (Fig. 2, 3). Ore reserves are 183 000 t grading 0.7% Cu and 3 ppm Ag

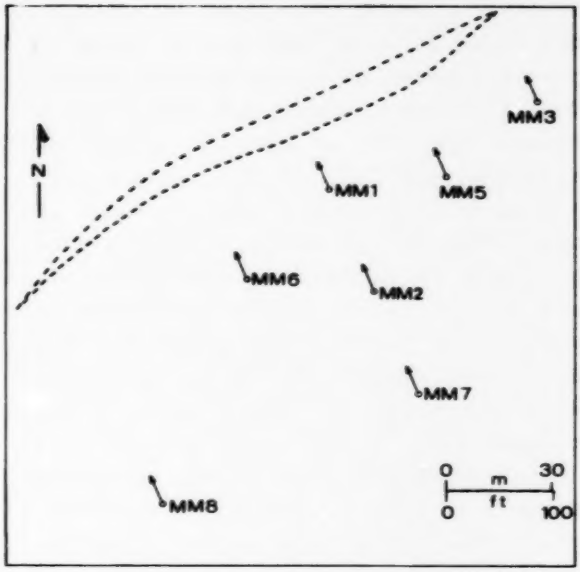

Fig. 2 - Plan showing location of principal drillholes at the McMaster property; the electromagnetic anomaly at surface is indicated in dashed outline. Data are from assessment files, New Brunswick Mineral Resources Branch, Bathurst.

(Davies and McAllister 1980). Assays obtained by Anaconda Company show that Pb and Zn in the sulphide zone are mostly at nil levels; the highest values reported for the main part of the deposit are 0.10% Pb over 3 m and 0.10% Zn over approximately 1 m.

SULPHIDE DISTRIBUTION

Anaconda Company delimited the mineralized zone with 8 holes drilled between 1957 and 1974. In drillhole MM-1 (Fig. 3) the thickest continuous intersection of massive sulphides has a core length of 2.6 m. At this site the zone of "mainly massive sulphides" (Fig. 3) consists of two massive layers that bracket about 2 m of phyllite in which the content of disseminated sulphides varies from almost nil to almost massive in thin layers. Deeper in the drillhole, the zone of "mainly disseminated sulphides" (Fig. 3) consists largely of sulphide-poor phyllite in which some layers are rich in fine-grained disseminated sulphides; one layer, only a few centimetres thick, is massive.

In drillhole MM-2 the sulphide sequence is similar in that two massive sulphide layers are again present and are separated by phyllite with abundant disseminated sulphides. However, the thicker of the massive layers in this case is much reduced and has a core length of slightly less than 1 m.

Little sulphide was intersected in drillhole MM-7: the main mineralized zone is represented by 0.25 m of disseminated sulphides. The massive section contains 0.5% Cu and negligible Zn and Pb.

Continuity of the massive sulphides along strike is indicated by significant sulphide intersections in drillholes MM-5 and MM-6 (Fig. 2). In MM-5 the initial intersection consists of 1.2 m of massive sulphides that are succeeded by about 9 m of phyllite with 10 to 50% disseminated sulphides, and then 4.5 m of massive sulphides. This sequence is similar to the sulphide distributions

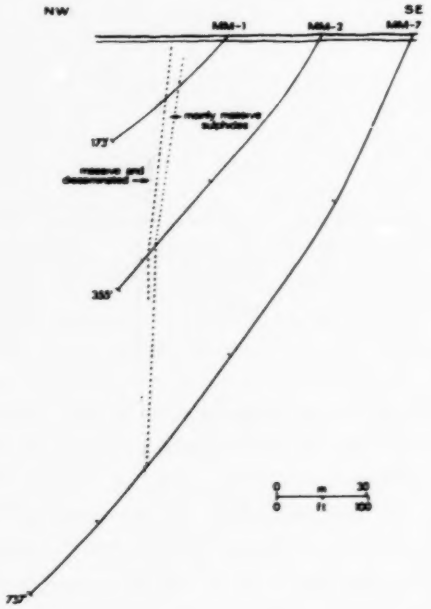

Fig. 3 - Drillhole cross-section showing distribution of massive and disseminated sulphides.

obtained in drillholes MM-1 and MM-2. In drillhole MM-6 (Fig. 2) the massive sulphides occur in a single layer that is almost 8 m thick and is succeeded downhole by about 9 m of disseminated sulphides.

The projected northeastward and southwestward strike extensions of the sulphide zone were not encountered by drillholes MM-3 and MM-8 (Fig. 2). Both holes were of sufficient length to make the expected intersections, but both are sulphide-barren.

FAULTS

Brecciated zones, slickensides, and narrow seams of gouge were observed in drill cores from most of the holes. These are also recorded in Anaconda's drill logs, together with other indicators of possible faulting, such as intense crenulation, ground-up core, and poor core recovery. Attempts to correlate these signs of faulting into a rational fault pattern have not been successful. For example, cores from drillholes MM-5 and MM-6 indicate that a fault occurs adjacent to the northern side of their sulphide intersections. Vertical projection to surface shows that the strike of the assumed fault coincides with the trace of the EM anomaly (Fig. 2). Several intersections showing faulting in drillhole MM-8 also are in an appropriate position for fault continuity along strike. In drillhole MM-1, however, continuation of the fault is not evident. Thus, the correlations apparently are incorrect, although it is noteworthy that the strike of the assumed fault approximately coincides with those of regional faults mapped by Fyffe (1974).

Attempts to correlate other fault occurrences on the property have met with similar difficulties. Lateral pinch-out of the sulphide body is rapid, but there is no evidence to indicate that the mineralized zone is part of a larger body offset by cross-faults.

MINERALOGY

GENERAL FEATURES

The principal sulphide in both the massive and disseminated zones is pyrite. In the massive zone most of the sulphidic rock consists of compact masses of pyrite grains with interstitial quartz and little else (Fig. 4). In the disseminated zone the pyrite grains generally make up several per cent of the rock, but abundance is highly variable normal to the stratigraphy. Thus, selected parts of the strata within the disseminated zone may contain a negligible amount of sulphide whereas other thin layers may be almost massive pyrite.

Although one might expect that thin layers of massive sulphides would be gradational to thicker layers, thereby leading to an arbitrary boundary between the disseminated and massive zones, such progression is generally not the case either at McMaster or at other New Brunswick stratiform deposits. Rather, the sulphides that are categorized as massive usually can be demarcated with ease because they occur in disproportionately thick layers which have sharp contacts. At McMaster, the initial downhole intersection of sulphides is usually an abrupt penetration into a massive zone, and subsequently into disseminated mineralization. This sequence corresponds with a typical hanging wall to footwall progression in stratiform deposits, and suggests that stratigraphic tops at McMaster face southeast.

PYRITE

Pyrite at McMaster varies from framboid-sized to grains >0.5 mm. The apparently coarse grain size of some of the sulphides arises from an abundance of pyrite particles which are commonly up to 2 mm in diameter (Fig. 4, 5). Some of these are single grains, and others are composites of several relatively coarse grains. Particles consisting of fine-grained, mosaic intergrowths have not been observed.

Acid etching of the particles has not revealed any distinctive features: polyframboidal structures are absent, and rare growth zoning seems to be restricted to small particles. In a few cases truncated growth zones show that only part of an original grain is present. The particles vary from homogeneous to sieve-textured, from angular to rounded, and from large to small (Fig. 4, 5); this diversity, which occurs even among

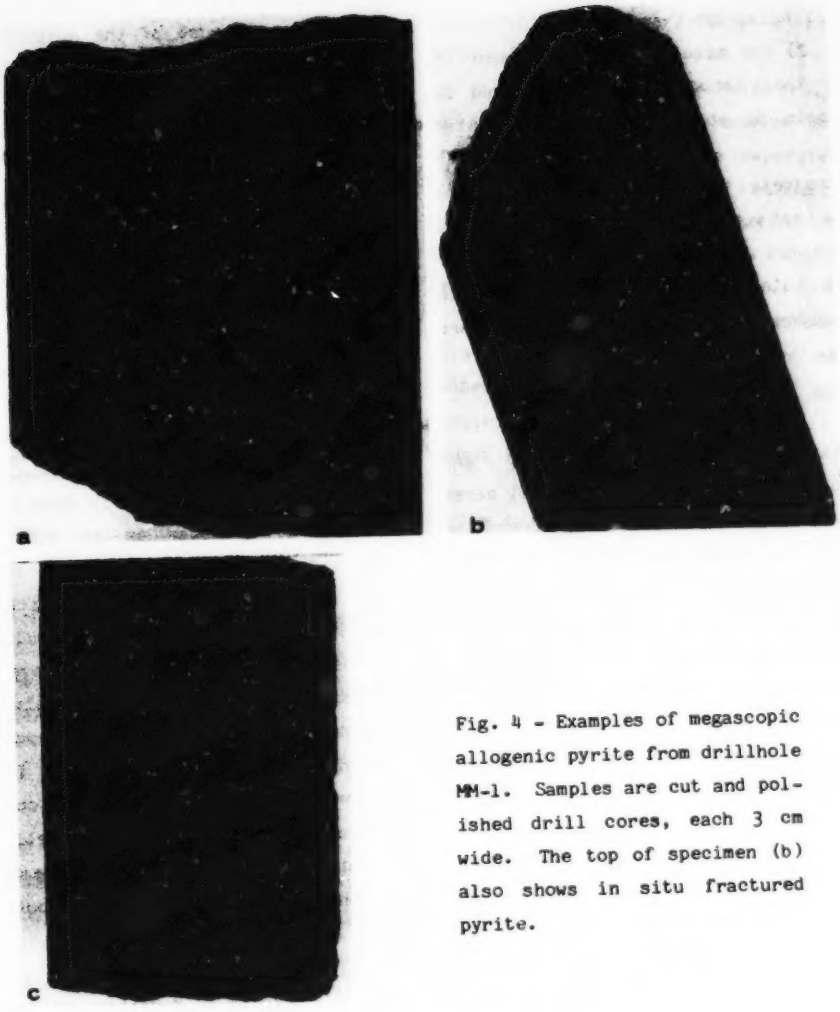

Fig. 4 - Examples of megascopic allogenic pyrite from drillhole MM-1. Samples are cut and polished drill cores, each 3 cm wide. The top of specimen (b) also shows in situ fractured pyrite.

adjacent particles, points to sedimentary deposition of transported material rather than primary, in situ crystallization. Pyrite of this type is referred to as allogenic.

Allogenic pyrite makes up the bulk of the massive sulphide zones and is also an appreciable component of the disseminated zones at McMaster. Thus allogenic pyrite is the principal sulphide constituent of the deposit; most of the remainder of the sulphides is primary pyrite which commonly occurs in compact masses of thin layers, some of which consist of framboid-size grains (Fig. 5). A few dispersed pyrite framboids occur in the disseminated sulphide zone, but these are rare and poorly formed in the massive zone. Colloform structures in primary pyrite are extremely rare, but acid etching has shown that a few grains have crystal growth-zoning. Grain shapes of the primary pyrite vary from euhedral to much more common anhedral, and in a few polished sections the grain sizes, shapes, and sulphide associations are almost identical to those observed for the Caribou deposit (Jambor 1981).

In drillhole MM-1 (Fig. 3), the initial intersection of massive sulphides contains the largest allogenic particles, and average particle size diminishes downhole. This pattern is repeated in the second massive sulphide zone. In drillhole MM-2 (Fig. 3) the massive zone is preceded by about 0.7 m of abundant disseminated

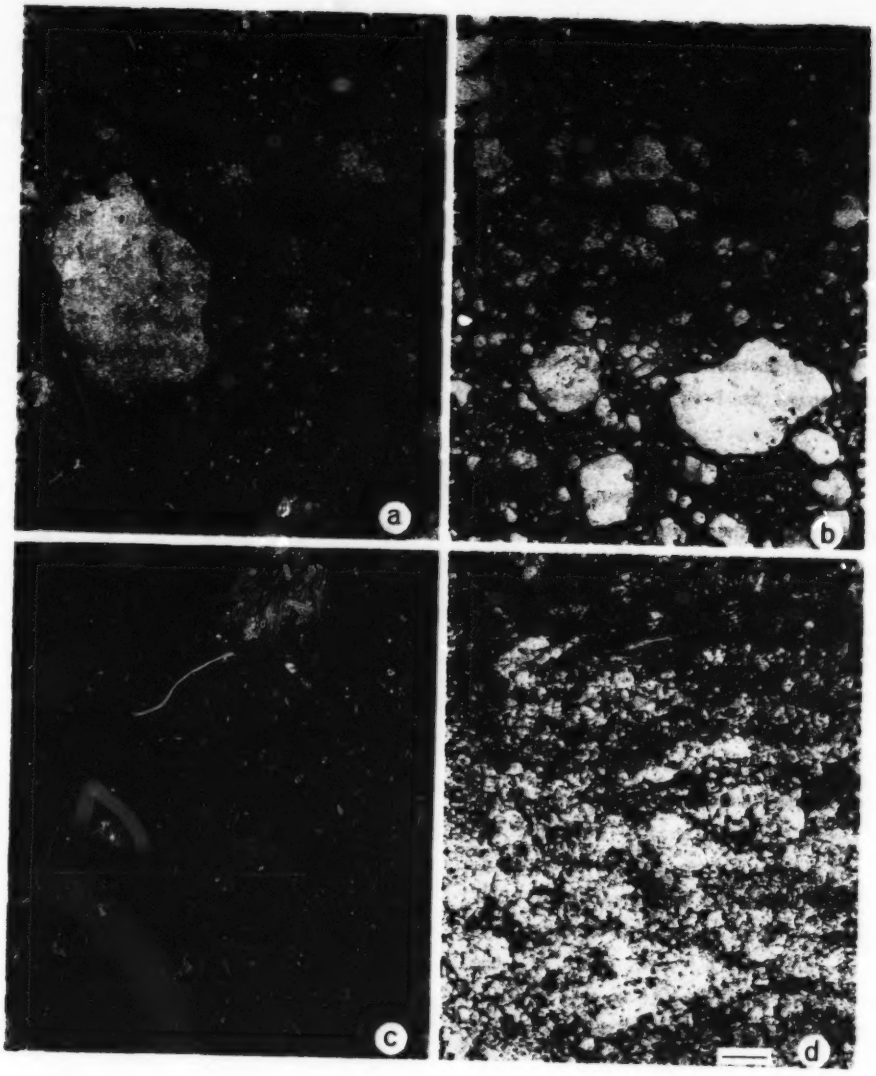

Fig. 5 - Examples of microscopic allogenic pyrite in polished sections of core from drillhole MM-2. (a) Fine-grained pyrite particles, with several of intermediate and one of large size, dispersed in a matrix of quartz (black); (b) similar, but with abundant intermediate-sized particles; (c) very large particle in a less sulphide-rich matrix; (d) fine-grained massive pyrite with structure brought out by etching with HNO_3; sample is from about 1 m downhole from the preceding examples of allogenic pyrite. All photos were obtained with reflected light, oil immersion, at the same magnification. Scale bar represents 0.2 mm.

sulphides, including numerous allogenic particles. In the massive zone the largest allogenic particles are less than half the size of those in MM-1, and the downhole side of the massive zone consists partly of fine-grained pyrite in laminae. The fine-grained pyrite may be primary (formed in situ) rather than allogenic. In drillhole MM-7 (Fig. 3) minor disseminated pyrite precedes about 0.3 m of massive sulphides in which allogenic pyrite is mainly fine-grained. To summarize for the total cross-section, it seems that allogenic pyrite coarsens toward the southeast, but the main direction of coarsening is from depth toward the present surface.

The massive sulphide intersections in drillholes MM-5 and MM-6 are at about the same depth from surface as the sulphides in MM-2. However, in both MM-5 and MM-6 the size and abundance of coarse allogenic pyrite are similar to those of MM-1, though the downhole diminution in partice size is much less evident. These variations, together with the absence of sulphides in drillholes MM-3 and MM-8 (Fig. 2), suggest that the allogenic pyrite was deposited in a paleotrough or channel having a northerly strike.

CHALCOPYRITE

More than half of the chalcopyrite at McMaster occurs as patches and veinlets along the grain boundaries of pyrite, and most of the remainder occurs along fractures in pyrite grains, or as veinlets that cut the grains. Only a minute amount of the chalcopyrite is present as small grains enclosed in pyrite, and trace amounts occur as blebs in sphalerite. Therefore, liberation of most of the chalcopyrite should not be difficult, especially as intergrowths with other base-metal sulphides are almost non-existent.

SPHALERITE AND GALENA

The exceptionally low zinc content of the McMaster deposit is evident in sulphide-rich polished sections, many of which either do not contain sphalerite or have only a few small, dispersed grains. The dispersed grains average about 25 µm in diameter and typically occur in interstices among pyrite grains, or interposed between pyrite and quartz.

In addition to meager dispersed sphalerite, the mineral occurs more abundantly and conspicuously in association with disseminated sulphides in phyllite. In these occurrences the sphalerite is in patches, up to 0.2 mm in diameter but usually with irregular outlines, which are generally concentrated in a few laminae and absent in most. Small amounts of finer grained galena and chalcopyrite are commonly with the sphalerite, and this type of association accounts for the major part of the galena in the deposit. The remainder of the galena occurs as sparsely disseminated grains with pyrite.

The most abundant sphalerite and galena observed in this study are in two samples from the downhole side of the disseminated zone in drillhole MM-6. One of the samples also has a massive layer, about 0.5 cm thick, in which pyrite grain size averages less than 15 µm; many of the grains are growth-zoned, a few small colloform masses are present, and disseminated arsenopyrite grains occur with the pyrite. Relatively abundant sphalerite and minor galena occur in the gangue and in interstices among the pyrite grains. The grain sizes, textures, and associations are identical to those observed in many samples from the Caribou deposit (Jambor 1981).

OTHER SULPHIDES AND RELATED MINERALS

Pyrrhotite is present in many of the polished sections, but is quantitatively insignificant. The mineral occurs as bleb inclusions in allogenic pyrite. The blebs average less than 15 µm in diameter, and usually only one or two are present in an individual pyrite grain.

Traces of lead-bismuth sulphosalts have been found as minute inclusions in pyrite. Microprobe analyses of three grains, each from a different footage in drillhole MM-5, gave low totals which are attributed to analytical difficulties arising from the small size of the inclusions rather than to missed elements (Table 1). Two of the analyses have element proportions that approximate the formulas of aikinite ($PbCuBiS_3$) and gla-

Table 1 - Microprobe analyses of lead-bismuth sulphosalts

wt %	MM-5-243	MM-5-260	MM-5-281
Pb	19.8	32.4	13.2
Cu	6.0	11.0	4.3
Bi	54.6	38.8	64.1
S	17.5	16.5	17.3
	97.9	98.7	98.9
mol. ratios			
Pb	1.00	1.00	1.00
Cu	0.98	1.11	1.06
Bi	2.72	1.19	4.80
S	5.69	3.30	8.44

Microprobe analyses at 20 kV, specimen current 0.028-0.035 microamperes; standards: synthetic Cu_2S, matildite, synthetic ZnS, meneghinite, enargite, synthetic and natural tetrahedrite.

dite ($PbCuBi_5S_9$). The other analysis has the lowest weight per cent total and the element proportions therefore are less certain; the unadjusted analysis corresponds to $Pb_{1.00}Cu_{0.98}Bi_{2.72}S_{5.69}$, which roughly approximates the composition of krupkaite ($PbCuBi_3S_6$).

A bleb of native bismuth, about 2 µm in diameter, occurs as an inclusion in allogenic pyrite in the massive sulphide zone in drillhole MM-6. The fine-grained, sphalerite-rich, Caribou-type sulphides from this hole also contain a grain of tennantite (Table 2). The pyrite in this polished section is accompanied by several grains of arsenopyrite of similar size, and rare scattered grains of arsenopyrite have been noted in various other samples.

In addition to the three samples from drillhole MM-5 that contain Pb-Bi sulphosalts, another contains a veinlet of bismuthian tetrahedrite in pyrite (Table 2); the four occurrences emphasize the bismuth-rich rather than antimony-rich character of the McMaster sulphide assemblage.

The only other sulphides noted in the McMaster cores are digenite with a bit of associated covellite, and small amounts of an unidentified copper-iron sulphide. The digenite and covellite occur sporadically and sparingly as thin rinds on a few chalcopyrite grains in quartz, and at the margins of some chalcopyrite veinlets that follow contacts between pyrite and quartz. Most of the digenite and covellite occur in cores from the uphole side of MM-1, a site that fits with the textural indications of supergene alteration.

Also present in MM-1 are several irregular grains of the unidentified copper-iron sulphide; it has replaced chalcopyrite and has in turn been partly replaced by rims and veinlets of digenite-covellite (Fig. 6). Grains of the copper-iron sulphide, although associated with the massive sulphides, occur only in the silicate-rich parts of the cores. The grains are brownish in reflected light, are strongly anisotropic, and all contain abundant fine-grained lamellae and spindles of chalcopyrite (Fig. 6). For the best chalcopyrite-free areas, microprobe analyses using wavelength spectrometry gave Cu 54.1, Fe 13.3, S 32.2, total 99.6 wt %. This corresponds to $Cu_{.851}Fe_{.238}S_{1.004}$, which has an excess of positive charges if all the copper is divalent. Recalculation of the results for 12 formula atoms gives $Cu_{4.88}Fe_{1.36}S_{5.76}$, and 8 formula atoms gives $Cu_{3.25}Fe_{0.91}S_{3.84}$. Despite the charge imbalance,

Table 2 - Microprobe analyses of tetrahedrite and tennantite

			29 atoms	
wt %	MM-5-275	MM-6-266	MM-5-275	MM-6-266
Cu	33.7	40.1		
Ag	0.0	0.0	11.9	11.8
Fe	3.6	3.2		
Zn	5.6	7.4		
Sb	13.6	0.0		
Bi	18.5	0.0	4.0	3.7
As	1.7	19.1		
S	23.9	29.4	13.1	13.5
	100.6	99.1		

Analytical conditions and standards are as given in Table 1.

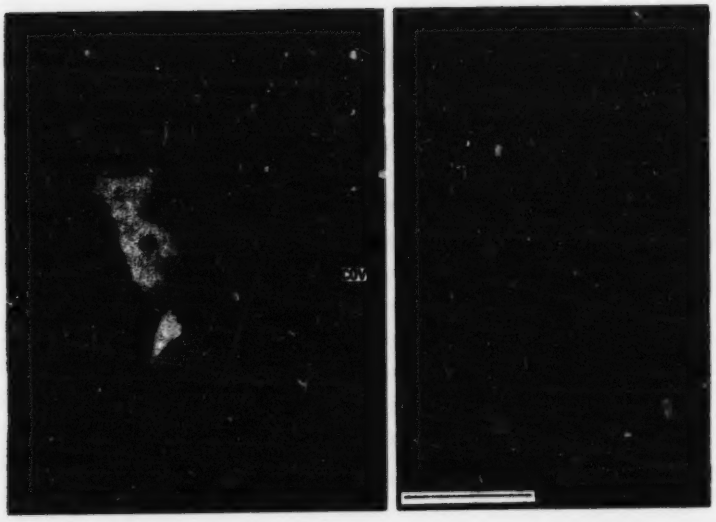

Fig. 6 - Unidentified copper-iron sulphide with relict grains of chalcopyrite (cp) and a replacement rim of covellite (cov) and digenite. Grain on the left contains oriented spindles of chalcopyrite and that on the right has slightly coarser chalcopyrite lamellae. Reflected light, oil immersion. Both photos at same magnification; bar scale represents 35 micrometers.

these results, together with the optical properties, indicate that the McMaster mineral is similar to nukundamite (or so-called idaite) as defined by Rice et al. (1979). Nukundamite has the empirical formula $Cu_{3.37}Fe_{0.66}S_{3.97}$ on the basis of 8 atoms. Crystal-structure analysis of synthetic nukundamite (Sugaki et al. 1981) indicates that the ratio of copper and iron atoms apparently is constant at 3.4 to 0.6.

Attempts to confirm the tentative identification of the McMaster sulphide by X-ray powder diffraction patterns were unsuccessful. Although the grains of the mineral are fairly small and inclusions of chalcopyrite are unavoidable, X-ray spindles prepared under the microscope seemed to contain sufficient material to give at least weak powder patterns of the sulphide mixtures. Nevertheless, the diffraction lines obtained are somewhat diffuse but consistently seem to match the strongest lines for chalcopyrite only; no second phase, which should have been the more abundant mineral, is detectable.

Magnetite, an important component in some of the Bathurst-area deposits, occurs at McMaster only as minute inclusions in coarse-grained allogenic pyrite. No silver minerals were observed in the McMaster samples. Chemical analyses of five pieces of massive-sulphide drill core gave an average of only 2.8 ppm Ag (Table 3).

Table 3 - Chemical analyses of McMaster massive sulphide samples

Drillhole No., footage	wt %						ppm
	Cu	Zn	Pb	As	Sb	S	Ag
MM-1-94'	0.65	0.15	0.01	0.03	<0.05	38.46	3.3
-106'	4.21	0.06	0.01	0.03	<0.05	38.43	5.8
MM-2-298'	0.59	0.01	0.01	0.04	<0.05	42.15	1.7
-299'	0.70	0.03	0.01	0.04	<0.05	38.00	1.3
MM-7-558'	0.42	0.05	0.04	0.05	<0.05	40.79	1.7

Analyses by Chemical Laboratory, CANMET.

SILICATES

Aside from its cupriferous character and preponderance of allogenic pyrite, the McMaster deposit is also distinct from most others in the district in that the non-sulphide minerals accompanying the massive sulphides are almost exclusively quartz and chlorite. The only carbonate mineral detected in the study is siderite that occurs in trace amounts as microscopic inclusions in allogenic pyrite, and as disseminated grains in quartz-rich layers in barren phyllite.

In most massive sulphide specimens the principal silicate is quartz, which is usually accompanied by small amounts of chlorite. The quartz occurs either interstitially among abundant sulphides, or as the matrix where sulphides are sparser. Although most quartz grains are anhedral and lack distinctive features such as undulatory extinction or pronounced ribbon structure, commonly the grains are slightly elongate and in subparallel arrays. The prevalent direction of elongation is along bedding, but it is also common to have the long axes of the quartz grains perpendicular to contacts with pyrite. Thus the quartz arrays extend outward from pyrite grain boundaries and follow the configuration of quartz-pyrite contacts rather than following the bedding or schistosity. These relations suggest that primary, in situ crystallization of quartz occurred during accumulation of the massive sulphides.

Small amounts of chlorite are associated with interstitial quartz in most massive sulphide specimens, and in a few of these specimens chlorite is the predominant silicate. The habit and occurrence of both minerals are similar, and in some cases the chlorite apparently has replaced quartz. The ratio of chlorite to quartz is lower in massive sulphides than in rocks with only a moderate sulphide content.

OTHER MINERALS

Granules of rutile, only occasionally present in sulphide-rich samples, are common along the bedding in phyllite. The affiliation of rutile seems to be with rock-forming silicates rather than with sulphides. One specimen from drillhole MM-6 is unusual in that the contact between massive sulphides and chlorite is choked with fine-grained granules of rutile that apparently have been disrupted by a relatively immense "dropstone" of rutile, approximately 0.1 x 0.1 mm.

A few flakes of graphite occur in rocks containing disseminated sulphides, and in barren phyllite. These flakes and the occasional anhedral grains of amorphous hydrocarbon seem to have no direct relationship with the sulphide assemblage.

CHLORITIC ALTERATION

Host rocks in the vicinity of the massive sulphides contain abundant muscovite and lesser amounts of chlorite. As the sulphide zone is approached from the southeast there is an abrupt change from muscovite-rich to chlorite-rich phyllite (Fig. 7, 8). Most samples from the chloritic zone are completely devoid of muscovite; in the few that have traces of mica, it is always concentrated as a microscopically thin layer along bedding rather than dis ersed throughout the rock.

The distribution of the chloritic zones (Fig. 7, 8) shows that they are specifically associated with the massive part of the sulphide zone; in contrast, some of the disseminated sulphides are in chloritic rocks, whereas others have muscovite-bearing host rocks. Despite the change from muscovite to chlorite, the character of the host rocks seems to be otherwise unaffected until the contact with massive sulphides is reached. Several specimens at this contact, or very near it, show signs of substantial replacement of quartz by chlorite, and in two specimens the only silicate present is chlorite. In drillhole MM-5, strong chloritic zones and diminution of quartz precede the intersections of both of the massive sulphide lenses (Fig. 8). In all drillholes, quartz reappears upon penetration of the massive sulphides.

In summary, a chloritic zone of appreciable thickness is concentrated along the southeastern side of the massive sulphides and is apparently continuous along the strike length of the sulphides. Drillholes MM-3 and MM-8 (Fig. 2)

did not intersect recognizable sulphide zones, and thin-section examination of several specimens from MM-8 did not reveal a chlorite zone.

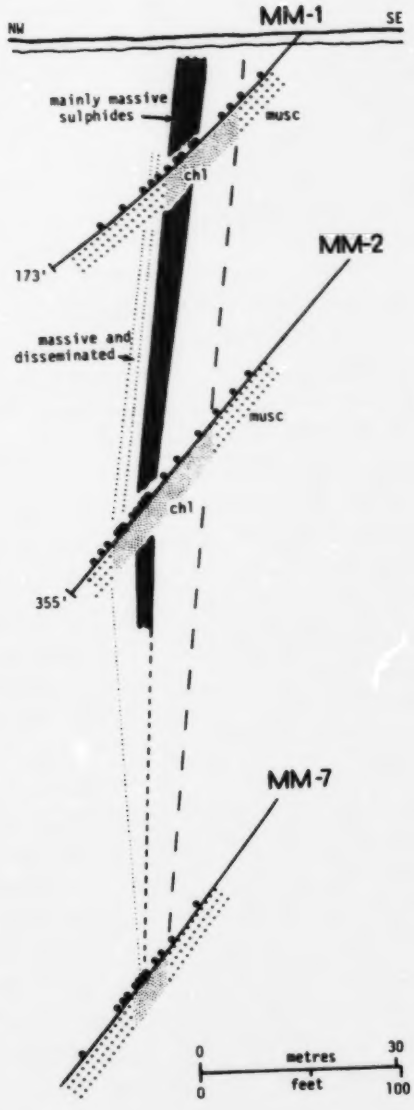

Fig. 7 - Cross-section of the McMaster sulphide zone showing the abrupt change from muscovite-rich (musc) to chloritic (chl) host rocks. Dots along the tops of the drillholes represent the positions of thin-section samples.

The limited data obtained for the chloritic zone indicate that at least a minor part of the chlorite is an alteration phenomenon related to proximity to the southeastern contact of the massive sulphides. Although the entire chlorite zone conceivably could be related to this contact, the thickness of the chloritic zone, the nature of the sulphides, and the apparent stratigraphic control of the chlorite (Fig. 7) suggest instead that the precursor rock-forming minerals of phyllite were exposed to a milieu that effected compositional changes in the layer-silicate components. In other words, the Mg-Fe-rich character of the rocks in the chlorite zone is thought to reflect penecontemporaneous conditions rather than subsequent alteration of potassium-rich rocks akin to the adjacent muscovitic phyllite.

Only locally did the depositional environment of the chlorite-bearing rocks straddle the period of massive sulphide accumulation (e.g., MM-2, Fig. 7), thus the timing of formation of the main chlorite zone, assuming the origin postulated above, is dependent on the direction of stratigraphic tops. If the disseminated sulphides preceded the deposition of massive sulphides, as is the usual sequence in Bathurst-area deposits, then the upward direction is southeast. One specimen of drill core from the southeastern massive sulphide-chlorite contact shows well-defined graded bedding, also with the tops facing southeast; unfortunately, this evidence is not proof as there is always some uncertainty associated with observations of drill cores split many years previously.

The possibility that the youngest strata are on the northwest side of the deposit cannot be discounted. Chloritic alteration in most Bathurst-area deposits is commonly absent or poorly defined; nevertheless, in deposits where chloritic alteration has been noted, such alteration invariably lies stratigraphically beneath the massive sulphides.

Base-metal zoning is commonly a useful indicator of stratigraphic directions, but metal grades at McMaster are low and segregation into Cu-rich versus Pb-Zn-rich zones is not evident. Thus the evidence favouring either of the possible

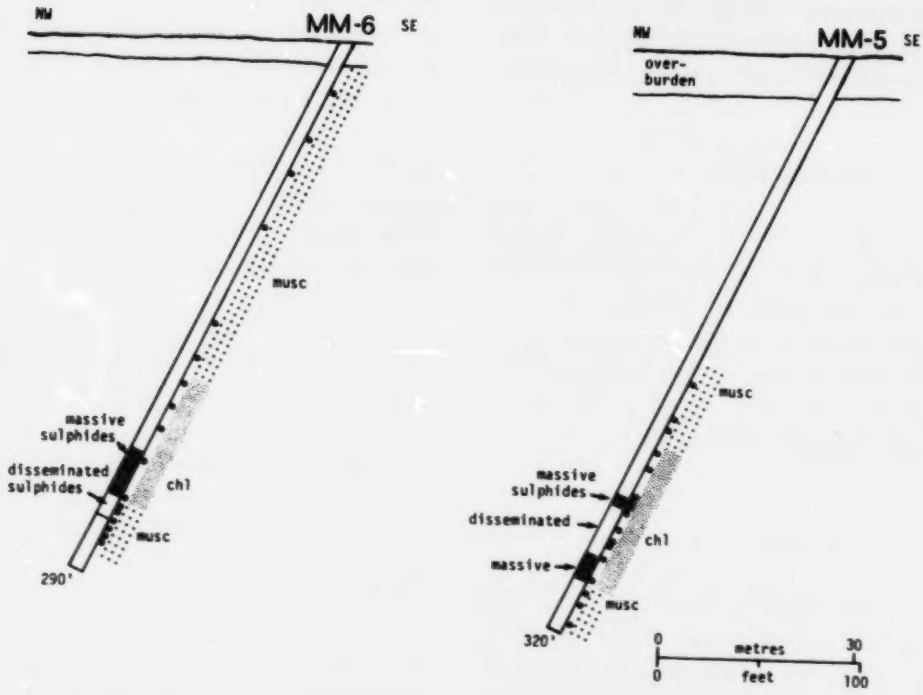

Fig. 8 - Cross-section of drillholes MM-5 and MM-6 (Fig. 2) showing the distribution of the chloritic and sulphide zones.

stratigraphic directions is not compelling. Even though the main part of the McMaster sulphides is allogenic, the sequence from disseminated to massive sulphides is considered to be slightly more positive than chloritic alteration in assessing top directions; on this basis the tenuous conclusion is that the deposit is overturned and that its stratigraphic top faces southeast.

METAMORPHISM

Although the McMaster deposit is in the northern part of what is depicted as the chlorite zone of greenschist regional metamorphism (Fig. 1), recent studies by Whitehead and Goodfellow (1978 a, b) have indicated that the chlorite zone probably is metamorphically much more complex: rocks near Murray Brook (Fig. 1) contain pumpellyite, garnet, and crossite zones, with the last thought to represent the blueschist facies of metamorphism. Skinner (1974) reported that sodic amphiboles occur in a narrow zone that extends along the northern area from near Murray Brook to beyond Rocky Turn (Fig. 1); this zone, which is correlative with the blueschist facies of Whitehead and Goodfellow, may include or be slightly north of the McMaster deposit.

The silicate assemblage at the McMaster deposit does not include stilpnomelane, biotite, or amphiboles, and is compatible with the chlorite zone of metamorphism. The fine grain size of primary sulphides is similar to that at the Caribou deposit and indicates that pervasive recrystallization with attendant grain coarsening has not occurred. A few of the much coarser allogenic pyrite grains contain numerous peripheral silicate inclusions; the size of the pyrite and the distribution and abundance of the inclusions are commonly indicative of recrystallized, metamorphic pyrite. On the other hand, the much coarser grain

size of the allogenic pyrite may be merely a reflection of primary crystallization in a relatively high-temperature, near-orifice environment.

ACKNOWLEDGEMENTS

The cooperation of Anaconda Company (Canada) Ltd., A. Buzas of Anaconda, and J.L. Davies of the New Brunswick Mineral Resources Branch is much appreciated. Technical assistance at CANMET was provided by J.M. Beaulne, Y. Bourgoin, P. Carrière, and E.J. Murray. The microprobe analyses were done by D.R. Owens.

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